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ABSTRACT

A research study investigated the effects on student performance and attitude of three different strategies for selecting lessons in a course in computer programing presented by computer. Sixty college students were randomly assigned to the strategies of student selection of lessons, program selection in the light of the student's past performance, and forced selection independent of the student's history. Several aptitude, performance, and attitude measures were applied, and no significant inter-group differences were found. These findings run counter to the common belief that students who control their course of study perform better and have more positive attitudes. The possibility exists that the particular computer programing course used in the experiment, since it was essentially linear in nature, did not lend itself to student control and that this tended to obscure differences which otherwise would have been manifested. To test this hypothesis, an additional experiment involving a nonlinear instructional-experimental environment is being planned. (Author/PB)

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COMPARISON OF STUDENT PERFORMANCE AND ATTITUDE UNDER THREE LESSON-SELECTION STRATEGIES IN COMPUTER-ASSISTED INSTRUCTION

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BY

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Three problem selection strategies (~~student selection~~, program selection weighted by past performance, and forced selection independent of student history) were compared in a CAI course in computer programming. Various measures of aptitude, performance and attitude were examined. No consistent difference was observed among the three groups. The results are discussed

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in terms of the specific experiment and the general problem of curriculum design for comparing path selection strategies. Continuing experimentation is described.

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TECHNICAL REPORT SUMMARY

This study investigated the effects on student performance and attitude of three different strategies for selecting lessons in a course in computer programming presented by computer. The focus of the investigation was a comparison of computer selection vs student selection of instructional material.[1]

A commonly held belief is that students prefer to exercise control over their course of study; this assumes that they are capable of making such decisions, and that provision for such control will be a motivating factor reflected in an increased rate of learning. Little experimental data exist to support this belief. In fact, it is not even known how much control students will exercise when given the option. This study was designed, in part, to examine the effect of student control on both performance and attitude.

The study was conducted using eight remote terminals linked by telephone lines to the PDP-10 computer at the Computer-assisted Instruction (CAI) Laboratory of the Institute for Mathematical Studies in the Social Sciences (IMSSS) at Stanford University. A simple and inexpensive device (Model-33 teletype) was used as the student terminal. The CAI program imposed no time constraints; students were free to spend as much time as they chose on any lesson.

The course, "Computer Programming in AID," was designed for one quarter or one semester of instruction in the Algebraic Interpretive Dialogue (AID), a mathematically oriented programming language. It

consists of 36 parallel sets of short and long lessons as well as tests and extra-credit problems. Long lessons cover the same material as the corresponding short lessons, but in greater detail. An outline of the course is shown in Table 1.

Three experimental conditions were established: free choice, no choice, and program choice. Students in the "free-choice" condition were permitted to alter their position in the course at any time. Students in the "no choice" condition followed a straight path through the long lessons, with a test after every fourth lesson, and were not allowed to alter the sequence of lessons. Students in the "program-choice" condition followed a modified path through the short lessons with a test after every fourth lesson. The progress of these students was monitored by the program, and the corresponding long lesson was presented when a student performed below a set criterion, either in a short lesson or on a test.

Sixty students, distributed between both schools and over the entire 1972-1973 school year, were selected as subjects for this study. Three equal groups were created by random assignment to each selection condition.

The measures used in the analysis were: the Computer Programming Aptitude Battery, two final examinations prepared by the project staff, the responses to an attitude questionnaire, the number of times a student signed on to the course, the number of minutes spent signed on, the number of lessons taken, the number of problems correct,

the number of problems attempted, the percentage correct, and the highest lesson completed.

Our results indicated no significant differences among the three conditions on any of the performance or attitude measures. It cannot be said, on the basis of these findings, that a curriculum offering extensive student control is either superior or inferior to a program-controlled sequence. In fact, it appears that the "free-choice" students did not make sufficient use of their choice option to alter dramatically the sequence of lessons.

The implications of these results deserve some discussion. A student's use of choice options is related to the curriculum he is studying, both in its content and in its instructional design. The subject matter taught in the AID course was organized in a hierarchical, cumulative set of lessons, each to some extent dependent on concepts and skills developed in earlier lessons. This inherently linear organization, although quite common in computer programming instruction, does not lend itself to student control over the curriculum, beyond skipping or reviewing items, as evidenced by the similarity of the sequences followed by the subjects in the three groups.

It is possible to construct a fundamentally nonlinear instructional-experimental environment in which program and student strategies can be examined more fully. Building on the results of the current study, we are developing and testing a very different CAI

curriculum. The course content will be the same--introductory programming--but one major feature distinguishes the new curriculum from the AID course. The instructional sequence will be intentionally nonlinear, i.e., it will be dependent on students' acquisition of skills in interrelated conceptual areas instead of their progress through a defined series of lessons. The curriculum driver will be capable of making decisions about students' abilities on the basis of an informational network of programming concepts, and will be capable of selecting an instructional task appropriate to students at their particular level. This design implies the possibility of exploring differences in the performance of those students whose selections are made by the program and those who are forced to choose problems that cannot, by the nature of the network design, be sequenced in a preplanned hierarchy. There will be no predetermined, recognizable "default" sequence, and to the students, the curriculum will appear as an individualized sequence of programming tasks.

One planned experiment will again involve program-selection and student-selection modes: in the program-selection mode all instruction, hints, and problems will be generated by the program as determined by its decision-making capabilities. In the student-selection mode, the problems and instructional hints will be specifically requested by the student.

INTRODUCTION AND BACKGROUND

Environment and Equipment

This study was initiated as a prelude to a more elaborate investigation of branching strategies. It was thought that the branching procedure used here could answer certain preliminary questions on the evaluation instruments and on the content of the course itself.

The study was conducted using four CAI terminals located at the University of San Francisco (USF) and four terminals located at De Anza College in Cupertino, California. The terminals were linked by telephone lines to the PDP-10 computer at the CAI Laboratory of IMSSS at Stanford University.

The Stanford CAI communication network supports approximately 200 terminals, ranging from Model-33 teletypes operating at 100 words per minute to high-speed cathode-ray tube displays operating at 10,000 words per minute. Although they provide no audio, visual, or graphic capabilities, teletypes are sturdy, low-cost devices that provide the student with a printed copy of his interaction with the instructional program.

The CAI terminals at USF were located in a classroom near the office of the College of Business Administration, under whose auspices the research program at USF was implemented. On weekdays, students had free access to the CAI terminals from 12 a.m. to 10:00 p.m., and on weekends as permitted by the scheduling of computer down-time.

Schedules were used to apportion terminal time; three terminals were available for advance sign-up in one-hour time blocks. The fourth terminal was available on a first-come, first-serve basis for one-hour periods. Under ideal operating conditions four terminals would have provided 200 hours of terminal time per week, enough to comfortably accommodate the approximately 50 students registered for the course during the fall semester. Scheduling problems did develop, however, and thus enrollment for the spring semester was kept under 25 in order to insure adequate access to the terminals.

The four terminals at De Anza College were located in the Data Processing Laboratory. The course was given by the Business and Data Processing Division and was open to all students. Eighteen students were enrolled for the fall quarter, 14 for the winter quarter, and 16 for the spring quarter. With this number of students no scheduling problems arose.

The CAI program imposed no time constraints on students working at terminals. Students had unlimited time to respond to each question, and to complete a lesson. The process of initiating interaction with the instructional program is called "signing on," and disconnecting from it, "signing off." When a student finished a lesson he was free to sign off, or to continue with another lesson. He was also permitted to sign off in the middle of a lesson.

Curriculum

The course, Computer Programming in AID, was designed for one quarter or one semester of instruction in AID. It consists of 36 sets of lessons plus tests and extra-credit problems. An outline of the course is presented in Table 1. AID resembles BASIC in its use of line numbers and in its relatively simple grammatical rules, but it differs from BASIC in that AID allows recursive procedures. The IMSSS implementation of AID is interpretive and provides students with diagnostic messages and flexibility in changing programs. Topics covered by the curriculum include conditional execution, loops, lists, two-dimensional arrays, standard functions, user-defined functions, and recursive functions (see Friend, 1973).

The AID course was extensively revised for use in this investigation. The revised curriculum is organized into four strands, containing Short Lessons (SL), Long Lessons (LL), Tests (T), and Extra-credit Problems (EX). Lessons in the LL strand cover the same material as those in the SL strand, but in greater detail. The average lesson from the SL strand has about 20 problems, while that from the LL strand has about 30 problems. Many of the problems in both types of lesson have from one to three subproblems.

The test strand contains nine tests. A test is designed to cover the immediately preceding four lessons. It contains 40 items, 10 for each of the four lessons.

The EX strand does not contain a lesson at each level; the EX lessons are listed in Table 1. An EX lesson typically contains from one to five programming problems, some of considerable complexity.

DESIGN AND EXPERIMENTAL PROCEDURES

Subjects

Two groups participated in this study. The first consisted of University of San Francisco students enrolled for academic credit in a course introducing the use of computers in business administration. These students are required to take a programming course, but are free to choose among several options. Thus, enrollment for this course was voluntary. The fall class numbered 49, 30 men and 19 women, and the spring class numbered 23, 16 men and 7 women. Subjects were mostly first-year students and none had prior programming experience.

The second group of students attended De Anza Junior College, and did not fulfill any requirements by enrolling in the AID course. The distribution of students enrolled was (a) for fall, 11 men, 7 women; (b) for winter, 9 men, 5 women; and (c) for spring, 9 men, 8 women.

Sixty students, distributed between both schools and over the 1972-1973 school year, were selected as subjects for the results reported below.

Experimental Conditions

The three experimental conditions designed for this study are Student Selection (SS), No Selection (NS), and Program Selection (PS). The conditions are distinguished as follows:

1. SS. A student in the SS group was permitted to alter his position in the course at any time. The use of three control characters was available to him.

Control Character	Action
CTRL-G	choose a different lesson and/or problem
CTRL-T	have the terminal print the answer to the current problem
CTRL-H	skip the current problem

The SS student was permitted to use AID at any time, whether the current problem involved writing a program or not.

2. NS. Procedures for the NS group were designed to guide the student on a straight path through the LL strand, with a test (T strand) after every fourth lesson. The control characters described above did not operate for the NS Group. A student was not allowed to alter the order in which his lessons were presented and he was permitted to use AID only for programming problems.

3. PS. The student in the PS group followed a modified path through the SL strand with a test after every fourth lesson. The control characters described for the SS student were not available to the PS student, and a student was permitted to use AID only for programming problems. The student's progress through the SL strand was modified in two different situations:

1. At the end of each SL the student's score was checked. If he answered 90 percent or more of the problems in the lesson correctly on the first try, he was sent to the corresponding EX lesson if one was available. If his score was below 75 percent, he was sent to the corresponding LL for further work. In either case, after completing the branch lesson he returned to the next lesson in the SL strand.

2. After each test the student's score was checked for the items related to each of the previous four lessons. He repeated the LL lessons related to those concepts on which his test performance fell below 75 percent. After taking the prescribed reviews the student returned to the next SL lesson following the test.

The 60 students were roughly matched on the basis of their performance on the aptitude battery given as a pretest at the beginning of the course. The three equal groups studied here (SS = 20, NS = 20, PS = 20) were created by random assignment.

Criterion Measures

Students were tested at the beginning of the semester using the Computer Programmer Aptitude Battery (CPAB), published by Science Research Associates. The CPAB is comprised of five separately timed tests, measuring the following skills and aptitudes: verbal meaning, reasoning, letter series (a test of abstract reasoning ability), number ability, and diagramming (using flow charts).

Several instruments were used at the end of the semester to evaluate performance and attitude. The project staff prepared a two-part final examination. Part A was an off-line, closed-book test covering the entire course. It contained 53 questions, some requiring constructed responses, others, multiple choice. It was designed to test (a) knowledge of AID syntax, (b) understanding of program flow, (c) ability to analyze a program and to predict its output, and (d) ability to construct or complete programming algorithms to solve a specific problem. Part B consisted of five programming problems that were to be written at CAI terminals. Students were permitted to use notes and the course handbook. For each problem they submitted a listing of their program and sample output. Parts A and B of the final examination can be found in Appendix A.

An attitude questionnaire was administered to USF students. The questionnaire (Appendix B) is a revision of one developed to evaluate a CAI project at Tennessee State University (see Searle, Lorton, Goldberg, Suppes, Ledet, & Jones, 1973). It contains 12

statements about the student's CAI experience. A seven-point scale was used to indicate the degree of agreement with with each statement.

Various parameters of student performance on the course were used. These performance characteristics were obtained from data collected by the instructional program. The program saved all student responses. Only first responses were used to determine the number of problems correct.

The full list of measures used in the analysis includes:

1. Performance on the CPAB
2. Performance on final examinations
   a. Test A (project off-line, closed-book examination)
   b. Test B (project on-line examination)
3. Responses to the attitude questionnaire
4. Number of times the student signed on to course (# SIGN ONS)
5. Total number of minutes spent signed on to course (MINUTES)
6. Total number of lessons taken (LESSONS)
7. Total number of problems worked correctly (# CORRECT)
8. Total number of problems attempted (# PROBLEMS)
9. Percentage correct (PERCENT)
10. Highest lesson completed (TOP LESSON)

ANALYSIS AND DISCUSSION OF EXPERIMENTAL RESULTS

Aptitude Measures

Scores on the CPAB for students in the three experimental groups are shown in Table 2. The CPAB test manual indicates that percentile norms for experienced computer programmers and systems analysts are based on the scores of personnel from a variety of business and industrial installations, including computer manufacturers. Norms for programmer trainees are based on the scores of applicants for jobs with civil service agencies and persons enrolled in basic-computer-systems training at universities or computer-manufacturer training sites. Approximately 80 percent of the experienced programmers and 50 percent of the programmer trainees were college graduates.

Table 3 shows a comparison between the experimental subjects' scores and the norms of the aptitude battery for both programmer trainees and experienced programmers. The average score for the experimental group, 62.06, lies in the 55th percentile on the scale for trainees and in the 9th percentile on the scale for experienced programmers.

The CPAB manual states that performance on the Letter Series Subtest is least affected by education and experience; this may well account for the experimental group's relatively high percentile rank (57) compared with rankings on other subtests on the experienced programmers' scale.

Performance on the CPAB proves to be a useful predictor of performance on the AID course. The correlations between scores on CPAB subtests and two performance measures, percentage correct in the course and score on Test A, are shown in Table 4.

Total score on the CPAB accounts for 46 percent of the variability in percentage correct in the course, and 32 percent of the variability in Test A scores. The claim by the developers of the CPAB that performance on the Diagramming Subtest is highly related to subsequent success in programming is supported by the results in Table 4. The two subtests with lowest predictive ability are verbal meaning and number ability. The AID curriculum uses numerical examples exclusively in providing programming problems; nevertheless, the subtests that depend on reasoning ability serve as better performance predictors.

Curriculum Performance Measures

Descriptive measures of progress in the curriculum for each experimental group are presented in Table 5. The average percentage correct over all lessons for all students was 72.48. Students signed on for sessions at the terminal an average of 59 times and worked, on the average, a total of 2056 minutes. They attempted, on the average, 1303 problems and covered over 36 lessons (including both short and long lessons). There were no significant differences among the three experimental groups on any of the measures of course usage and progress. The NS students, who took only the long lessons, spent more time at the terminals, and attempted more problems than students in the other two groups, but the differences were small.

Use of Choice Options

The SS students were allowed complete control over the selection of lessons. All students had a list of the lessons in the course and were told how to select lessons. The SS students made little use of this opportunity to control the sequence of lessons and, in effect, to 'individualize' their curriculum. The path through the course of the 20 SS students was compared with the standard order of lessons shown in Table 1 (lessons 1-4, test 1; lessons 5-8, test 2; etc.). Ten students showed no deviations from the standard pattern, three students took one or two lessons out of order, three students took three or four lessons out of order and the remaining four students took more than four lessons out of order. Thus, approximately three-fourths of the students made essentially no use of the freedom to change the order of their lessons.

The paths through the course chosen by the four students who deviated most from the standard order are shown in Table 8. Student 1 used the choice option to take tests out of order; in all but one case, he opted to take the tests early. Student 2 took an essentially straight path though the short and long lessons, occasionally skipping an LL lesson to return to it later, and, twice, to return to an EX lesson. Student 3 skipped ahead to work LL lessons out of order, but returned to work SL lessons systematically, skipping only SL11 and SL16. Student 4 skipped around a bit early in the course, but later used the choice option only to take tests out of order.

In almost no cases did students use the choice option to skip forward in the curriculum. Students were extremely conservative in the use of their freedom to sequence the course; most often they used this freedom to take tests out of order or to return to forms of lessons already taken.

Table 7 summarizes the choice of lesson types for the SS students. Students 1-4 are those whose paths are shown in Table 6. Of the remainder, one took LL lessons only, while five combined a mixture of SL and LL lessons in approximately equal numbers. The rest of the students (with only minor exceptions) worked only SL lessons. Thus, approximately half the students chose the fastest straight path through the course.

Final Examinations

A two-part final examination was administered by the project staff to students in the experiment. Results of this examination are shown in Table 8. Because of scheduling difficulties 13 students were unable to take Test B of the examination.

Although the mean scores for the three experimental groups do not differ significantly, the scores for the NS students were slightly higher on Test A and slightly lower on Test B than for the other groups.

Test A was an off-line, paper-and-pencil examination. Results of a linear regression analysis using performance on Test A as the dependent variable are shown in Table 9. The top lesson taken and the score on the CPAB together account for more than 50 percent of the variability in the Test A score.

Attitude Questionnaire

The attitude questionnaire (Appendix B) contains 12 items ranked by students from strong agreement (1) to strong disagreement (7). The mean response by condition to each question is given in Table 10.

Generalizing over all students, the strongest responses showed agreement with the statements in questions 1 and 3. These were "I worked as hard answering questions in the computer lessons as I do in the classroom" and "I like working at my own pace at the terminal," respectively. PS students agreed more strongly than the other groups with question 1 (means are SS = 2.588, NS = 2.632, PS = 1.824), and SS students agreed more strongly with question 3 (SS = 1.412, NS = 2.421, PS = 2.588).

Both of these results demonstrate favorable attitudes toward particular aspects of the CAI experience. The mean responses do not demonstrate a strong negative feeling toward CAI on any question.

Two of the attitude questions show relatively high correlations with some descriptive measures and with test performance; the results are shown in Table 12. The questions are No. 2, "I learned from the computer lessons as well as I would have learned the same lesson in the classroom," and No. 10, "I would like to participate in another CAI course." Students who took more lessons and answered more problems correctly tended to have favorable attitudes. Performance on Test B correlated with positive attitude on questions 2, 3, and 4.

There were no significant differences between conditions in responses to the questions, as shown by the results of an analysis of variance presented in Table 11. For all of the attitude questions, the between-groups degrees of freedom (d.f.) is 2, and the within-groups d.f. is 50. For significance at the .01 level, an F ratio of 5.06 is needed; at the .05 level, an F ratio of 3.18 is needed. None of the ratios found reach these significant values.

Item Analysis

A master list matching items on Part A of the final examination with the lesson each item tested was prepared by the author of the course, J.E. Friend. Student responses to items for which they had and had not taken the appropriate lesson are shown in Table 13.

The labels in the "Lesson Status" column of Table 13 are independent of the three experimental conditions. Each item in the examination tested material covered by both an SL and an LL lesson. For each item, each student falls into one of the "Lesson Status" categories by virtue of those lessons he completed. For example, the "Not Taken" category includes students from all three experimental conditions. The "SL Only" includes only SS and PS students; the "LL Only" includes only SS and NS students; and the "SL & LL" includes only SS and PS students.

Table 13 shows, for example, that of the 1367 incorrect responses tallied on the examination, 462 were made by students who had not taken either SL or LL lessons associated with the items, 455 were made by students who had taken the associated SL lesson only, 274 were by students who had taken the associated LL lesson only, and 176 were by students who had taken both the SL and the LL lessons associated with the item. There were 98 items skipped by students who had taken the lessons on which they were based, compared with 195 items skipped by students who were unfamiliar with the material on which the item was based. There were 349 correct responses made by students who had not

taken the appropriate lessons for the items. An examination of these responses revealed that 215 of them were to six questions that gave the student a binary choice (true-false, correct-incorrect), and it is likely that guessing played a large role in producing these correct answers.

Table 14 shows the percentage correct, incorrect, and not tried for all students, and percentage correct and incorrect based on total attempts. Apparently students who took only the LL lesson did substantially better (61.8 to 38.2 percent) than students who took only the SL lesson (51.7 to 48.3 percent). Students who took both the SL and LL lessons fell in between. This is not a surprising finding since most of those who took both lessons needed extra review and were thus not likely to be the best students.

SUMMARY AND CONCLUSIONS

The focus of this investigation was a comparison of computer-program-controlled selection and student-controlled selection of instructional material during one quarter or one semester of instruction in AID. The performance and attitude of 60 students were examined: 20 in the "student-selection" condition, 20 in the "no-selection" condition, and 20 in the "program-selection" condition.

Results indicated no significant differences among the three conditions on any of the performance or attitude measures, although there are interesting correlations among the measures over all students. On the basis of these findings, a curriculum offering extensive student control cannot be demonstrated to be either superior or inferior to a program-controlled sequence.

It is clear that the SS students did not make sufficient use of their choice option to alter dramatically the sequence of lessons, and in this sense, the original question of student vs program control cannot really be examined properly from the data collected.

A student's use of choice options is related to the curriculum he is studying, both in its content and in its instructional design. A curriculum may incorporate various degrees of linearity, branching facility, remedial content, dialogue capability, student performance analysis, parallel content strands, etc, and these features may be developed and combined so that they motivate a student either to exercise options or to accept obvious choices as they are offered.

The subject matter taught in the AID course was organized in a hierarchical, cumulative set of lessons, each to some extent dependent on concepts and skills developed in earlier lessons. This inherently linear organization, although fairly common in conventional instruction in the subject, does not lend itself to the exercise of student control of the curriculum beyond skipping or reviewing, as evidenced by the performance of the subjects of this study. The most effective lesson sequence, in their view, is the straight line of the original conceptual design. The SS students were explicitly encouraged to develop their own alternative strategies, and during the year this encouragement was repeated many times. Thus, it must be concluded that the linear paths were chosen in conscious preference to any individually developed algorithms, which resulted in some disappointment to the experimenters.

The experiment, therefore, does not properly attack the question of modes of control. However, it is possible to construct a fundamentally nonlinear instructional-experimental environment in which program and student strategies can be examined more fully. Partly on the basis of the inconclusive results of the current study, a very different CAI curriculum is being developed and is now in the initial testing stage. The course content will be the same--introductory programming--but one major feature distinguishes the new curriculum from the AID course. The instructional sequence will be intentionally nonlinear, i.e., it will be dependent on students' acquisition of

skills in interrelated conceptual areas instead of their progress through a defined series of lessons. The curriculum driver will be capable of making decisions about students' abilities on the basis of an informational network of programming concepts, and will be capable of selecting an instructional task appropriate to students at their particular level. This design implies the possibility of exploring differences in the performance of those students whose selections are made by the program and those who are forced to choose problems that cannot, by the nature of the network design, be sequenced in a preplanned hierarchy. There will be no predetermined, recognizable "default" sequence, and to the students, the curriculum will appear as an individualized sequence of programming tasks. Instruction will be given only in response to the students' difficulties and requests.

The new course, which will teach the BASIC programming language, is being designed to test selection strategies in a more fluid environment. In the PS mode, all instruction, hints, and problems will be generated by the program as determined by its decision-making capabilities. Note that this requires considerable error diagnosis and interactive capabilities. In the SS mode, the problems and instructional hints will not be given automatically by the program, but must be requested specifically by the student.

It is hoped that this design will facilitate experimentation with instructional control strategies in a technical field, and at the same time allow enough freedom in the curriculum to make a "strategy" meaningful and necessary.

TABLE 1

AID Lessons

Topic	Test	Lesson identifiers: Short lesson	Long lesson	Extra credit
1 How to use the instructional program		SL 1	LL 1	-
2 Using AID for arithmetic: The TYPE command		SL 2	LL 2	-
3 Order of arithmetic operations		SL 3	LL 3	-
4 Exponents and scientific notation		SL 4	LL 4	-
Test 1	T1			
5 The SET and DELETE commands		SL 5	LL 5	EX 5
6 Indirect steps, the DO command, the FOR clause		SL 6	LL 6	-
7 Stored programs: Parts and files		SL 7	LL 7	-
8 The DEMAND command and the TIMES modifier		SL 8	LL 8	EX 8
Test 2	T2			
9 Relations and the use of the "if" clause		SL 9	LL 9	EX 9
10 The TO command		SL 10	LL 10	EX 10
11 Debugging techniques		SL 11	LL 11	-
12 The indirect use of DO		SL 12	LL 12	EX 12
Test 3	T3			
13 More on debugging		SL 13	LL 13	-
14 The FORM statement		SL 14	LL 14	EX 14
15 Absolute value		SL 15	LL 15	EX 15
16 Loops		SL 16	LL 16	EX 16
Test 4	T4			
17 More on loops		SL 17	LL 17	EX 17
18 Loops and the FOR clause		SL 18	LL 18	EX 18
19 Debugging tools: STOP and GO		SL 19	LL 19	-
20 Loops with a DEMAND command		SL 20	LL 20	EX 20
Test 5	T5			
21 Lists		SL 21	LL 21	EX 21
22 More on lists		SL 22	LL 22	EX 22
23 Arrays		SL 23	LL 23	-
24 Nested loops and nested DO commands		SL 24	LL 24	EX 24
Test 6	T6			
25 More on arrays		SL 25	LL 25	EX 25
26 The LET command		SL 26	LL 26	-
27 Standard functions: SQRT, IP, FP, SGN		SL 27	LL 27	EX 27
28 SUM, PROD, MAX, and MIN		SL 28	LL 28	EX 28
Test 7	T7			

TABLE 1 (cont.)

Topic	Test	Short lesson	Long lesson	Extra credit
29 Conditional functions		SL 29	LL 29	-
30 Standard functions: DP, XP		SL 30	LL 30	EX 30
31 Boolean expressions: AND, OR, and NOT		SL 31	LL 31	-
32 More on Boolean expressions: LET and TV		SL 32	LL 32	-
Test 8	T8			
33 The function FIRST		SL 33	LL 33	EX 33
34 Standard functions: SIN and COS		SL 34	LL 34	EX 34
35 Standard functions: EXP and LOG		SL 35	LL 35	-
36 Recursive functions		SL 36	LL 36	-
Test 9	T9			

TABLE 2

Scores on the Computer Programmer Aptitude Battery

	Experimental condition					
	SS		NS		PS	
Part	Mean	S. D.	Mean	S. D.	Mean	S. D.
Verbal Meaning	12.90	4.15	13.35	6.36	14.35	4.29
Reasoning	9.15	3.51	9.15	3.97	9.00	4.43
Letter Series	11.00	4.03	11.05	5.31	12.65	4.08
Number Ability	11.60	3.58	11.10	3.22	10.40	3.18
Diagramming	15.80	8.77	17.40	10.39	17.80	9.44
Total	60.45	16.10	62.05	23.54	63.70	19.43

TABLE 3

Comparison of Subject and Test Norms

Computer Aptitude Battery

Subtest	Mean raw score	Percentile ranking	
		Scale 1[a]	Scale 2[b]
Verbal Meaning	13.53	46	15
Reasoning	9.10	61	17
Letter Series	11.56	66	57
Number Ability	11.03	54	20
Diagramming	17.00	54	9
Total	62.06	55	9

[a]Based on programmer trainee norms.

[b]Based on experienced programmer norms.

TABLE 4

Correlations Between Performance on CPAB Subtests

and Two Course Performance Measures

Subtest	Percent correct	Test A
Verbal Meaning	.315	.295
Reasoning	.554	.585
Letter Series	.560	.394
Number Ability	.280	.312
Diagramming	.643	.492
Total	.666	.564

TABLE 5

Measures of Progress in the Curriculum

	Experimental Condition			
	SS	NS	PS	Total
No. sign-ons	53.15	63.85	60.50	59.16
Minutes	1995.96	2187.55	1984.18	2055.89
Lessons	35.00	36.90	38.65	36.85
No. correct	876.10	1075.95	891.10	947.71
No. problems	1242.30	1479.00	1188.90	1303.40
Percent correct	71.20	71.80	74.45	72.48
lop lesson	25.30	29.45	24.30	26.35

TABLE 6

Choice of Path Through the Curriculum for SS Students

STUDENT 1

Lesson	SL[a]	LL	Test	EX
1	1			
2	2			
3	3			
4		4		
T1			5	
5		6		
6		7		
7		8		
8		9		
T2			10	
9		11		
10		12		
11	13			
12		14		
T3			15	
13		16		
14		17		
15		18		
16		19		
T4			21*	
17		20		
18		22		
19	23			
20		24		
T5			26*	
21		25*		
22		27		
23		28		
24		29		
T6			31*	
25		30		
26		32		
27		33		
28	34			
T7			39*	
29		35		
30		36		
31		37		
32		38		
T8			41*	
33		40		
34		42		
35		43		
36		44		

[a] Numbers show the order in which lessons were taken.
* Starred lessons were taken out of order.

TABLE 6 (cont.)

STUDENT 2

Lesson	SL	LL	Test	EX
1	1	2		
2	3	4		
3	5	6		
4	7	8		
T1			9	
5	10	11		12
6	13	14		
7	15	16		
8	17	18		
T2			19	
9	20	21		22
10	24	23		
11	25	30*		
12	26	31*		
T3				27
13	28	29		
14	32	33		
15	34	35		
16	36	37		
T4			38	
17	39	40		41
18	42	43		46*
19	44	45		
20	47	48		49
T5			51*	
21	50	52		
22	53	55*		59*
23	56	54		
24	58	57		
T6			60*	
25	61	62		63
26	64	65		

TABLE 6 (cont.)

STUDENT 3

Lesson	SL	LL	Test	EX
1		1		
2	2			
3	3	5		
4	6			
T1				
5	7	10*		8
6	9	4*		
7	13	17*		
8	14	11*		15
T2			16	
9	18	12*		
10	19	20		
11		24		
12	26	25		
T3			23*	
13	27	28		
14	30	29		
15	31	21*		
16		22*		
T4				
17	32	33		
18	34			
19	35			
20	36	37		
T5			38	
21	39			
22	40			
23	41			
24	42			
T6			43	

TABLE 6 (cont.)

STUDENT 4

Lesson	SL	LL	Test	EX
1	1	3*		
2	2	4		
3	10*	6		
T1			5*	
5	16*	8		
6	13	12		
7	17	14		
8	18	15		
T2			9*	
9	19	20		
10		21		
11		22		
12		23		
T3			24	
13		25		
14		26		
15		27		
16		28		
T4			29	
17		30		
18		31		
19		32		
20		33		
T5			34	
21		35		
22		36		
23		37		
24		38		
T6			39	
25		40		
26		41		
27		43		
28		44		
T7			42*	
29		45		
30		46		
31		47		
32		48		
T8			11*	
33		49		
34		50		
35		52		
36		53		
T9			51*	

TABLE 7

Types of Lessons Taken by SS Students

Student	Number of lessons	
	SL	LL
1	5	22
2	26	26
3	21	16
4	8	27
5	24	0
6	3	6
7	23	0
8	21	0
9	0	22
10	21	0
11	20	4
12	16	6
13	11	17
14	16	13
15	12	20
16	10	13
17	23	6
18	18	1
19	26	1
20	27	2

TABLE 8

Scores on Project-designed Final Examination, Number Correct

	Condition					
	SS		NS		PS	
	N	Mean	N	Mean	N	Mean
Test A	20	22.70	20	27.85	20	24.50
Test B	15	15.73	16	13.00	16	14.37

TABLE 9

Step-wise Regression Summary Table with Test A

as Dependent Variable

Step	Variable	Multiple r	Multiple r^2	Last regression coefficient
1	Top lesson	.5650	.3192	.5364
2	Total problems	.7296	.5323	.2277
3	Sign-ons	.7534	.5676	.0429
4	Experimental condition	.7556	.5709	.8018
5	Total lessons	.7573	.5735	-.0866
6	Total minutes	.7581	.5747	.0005

Note.--Last constant used = -5.3006.

TABLE 10

Scores on Attitude Questionnaire Items

Question	Condition			Total	Positive or or negative statement (P,N)
	SS	NS	PS		
1	2.588	2.632	1.824	2.358	P
2	3.294	3.105	3.941	3.434	P
3	1.412	2.421	2.168	2.151	P
4	5.059	4.474	4.471	4.660	N
5	4.471	3.579	3.529	3.849	P
6	4.118	4.105	5.059	4.415	P
7	4.882	4.632	5.529	5.000	N
8	3.176	3.263	3.824	3.415	P
9	3.647	4.263	3.059	3.679	N
10	4.176	3.368	4.588	4.019	P
11	3.765	4.526	3.706	4.019	N
12	4.294	3.737	4.000	4.000	P

TABLE 11

Analysis of Variance Among Experimental Conditions on Attitude Questionnaire

Question	F Ratio
1	1.483
2	0.844
3	2.702
4	0.440
5	1.137
6	1.333
7	1.573
8	0.481
9	1.729
10	1.298
11	1.457
12	0.336

TABLE 12

Correlations Between Attitude and Performance Measures

Question	Measure	Correlation
Question 2.		
"I learned from the computer lessons as well as I would have learned the same lessons in the classroom."	Lessons	-.4484
	No. correct	-.5418
	Top lesson	-.4929
Question 10.		
"I would like to participate in another CAI course."	Lessons	-.4951
	No. correct	-.5307
	Top lesson	-.5451
Question 3.		
"I like working at my own pace at the terminal."	Test B	-.5036
Question 4.		
"I would prefer competing with my fellow students in the classroom rather than working at computer lessons."	Test B	.4094

TABLE 14

Responses to Final Examination Items: Percentage of Students Responding Correctly and Incorrectly

Lesson status	Percentage				
	Based on total taking test			Based on total attempting item	
	Correct	Incorrect	Not tried	Correct	Incorrect
Not taken	34.7	49.5	19.4	43.0	57.0
SL only	49.7	46.4	3.9	51.7	48.3
LL only	58.1	35.9	6.0	61.8	38.2
SL and LL	52.0	44.4	3.5	53.9	46.1
Total	50.4	40.8	8.8	55.2	44.8

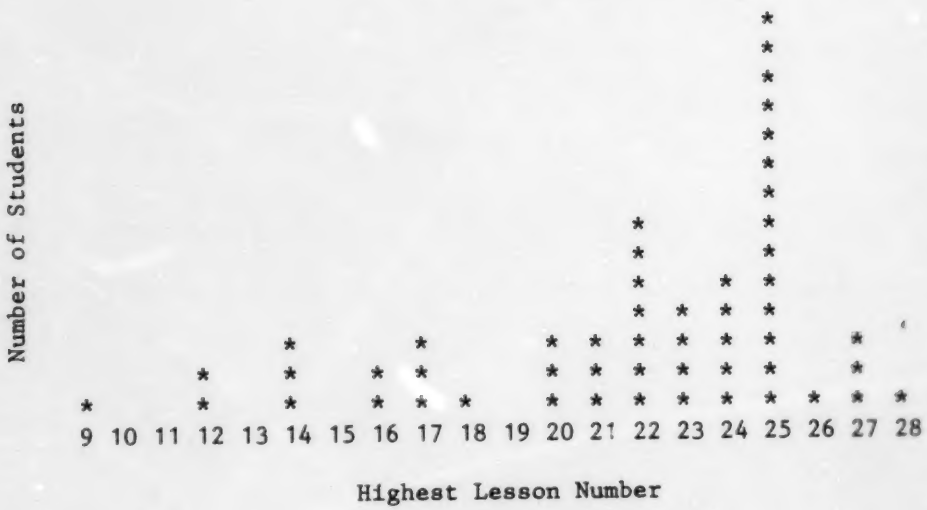

Fig. 1. Highest lesson completed in AID course.

Appendix A

Introduction to AID Programming 1972-73
Final Examination

Instructions to Examiners

The final examination for the course "Introduction to AID Programming" consists of two parts: Part A is a 50-minute paper-and-pencil test, and Part B is a 50-minute open-book programming test. If the two parts must be given on the same day, they should be given in two separate sessions with a 5-10 minute rest period between sessions.

Part A. No books or notes of any kind are to be allowed during Part A of the final examination. The students are not to be allowed to use a teletype. All that is needed is a copy of Part A and a pen or pencil.

Hand out the copies of Part A with instructions not to open the test until told to do so. Ask the students to read the instructions on the cover page. Allow about 1 minute for this before giving the signal to start the test. Allow 50 minutes for Part A.

There are 50 test items in Part A. Each correct answer counts 1 point, for a total of 50 points. No partial credit will be given for the items in Part A. There will be no penalty for incorrect guesses (no points will be subtracted for wrong answers).

Part B. Students should be told beforehand that Part B will be an open-book test. They should be asked to bring any books and notes that they wish, including the Supplementary Handbook for Introduction to AID Programming.

At least two days before the students are to take Part B of the final examination, but after their last working session, inform your Stanford representative of which students will take Part B, and when. The computer record for each student will be set so that the next time he signs on he will be automatically switched to the AID interpreter so that he will be able to do the programming problems in Part B.

Before handing out copies of Part B, ask the students to sign on. Check to be sure each student has been automatically switched to the AID interpreter. If this does not happen, call Stanford immediately.

After each student is signed on, and is in communication with the AID interpreter, hand out the copies of Part B with the instruction not to open the test until told to do so. Allow the students time to read the instructions on the cover page--about 1 minute--and then give the signal to start. Allow 50 minutes for Part B.

There are 5 programming problems in Part B. Each problem counts 10 points, for a total of 50 points. Partial credit will be allowed for partially correct programs.

Here is a brief grading guideline to help you answer questions that students may ask during the final examination:

(1) The programs are expected to function correctly only for the range of values of the input variables specified in the problem. Thus, for Problem 2, the program need not cope with negative values of H, and for Problem 3, the program need function correctly only for weights between 0 and 16 ounces, inclusive.

(2) The length of the program is immaterial, only the correctness of the results will be considered in grading.

(3) There are several methods of solving each of the problems in Part B, and no one method is preferred. Any method that provides a general solution and produces correct results will be considered correct.

(4) For Problems 1, 2, 3, and 4, specific test values of the input variables are given. However, a program that produces correct results for these test values only, and not for other values of the input variables, will not be considered a correct solution; the program must provide a general solution.

TURN IN ALL TEST PAPERS TO STANFORD. These tests will be used for research purposes and will not be returned. If you wish to use these tests for assigning grades to your students, you may grade the tests and record the grades before you turn them in to Stanford; otherwise, you need not grade the tests.

Introduction to AID Programming 1972-73

Final Examination

Part A

(50 points)

****

DO NOT TURN THE PAGE.

****

Name _____

Student number _____

Instructor's name _____

Name of school or college _____

Date _____

Instructions: You may not use books, notes, or other materials during this part (Part A) of the final examination. There are 50 test items in Part A. No partial credit will be given. You will not be penalized for guessing (no points will be subtracted for wrong answers). You will have 50 minutes to complete the test.

****

DO NOT TURN THE PAGE UNTIL INSTRUCTED TO DO SO.

****

Rewrite each command correctly.

1. IF X < 2 DUE PART 3

_____

2. DO STP 3.6 FOR X = 1 TO 100

_____

3. TYPE X(Y+Z) AND X(Y-Z) AND X(Y ÷ Z)

_____

Select the expression(s) that are equivalent to the given expression.

4. A/B - C/D + E

___ (A/B) - (C/D + E)

___ (A/B) - (C/D)+ E

___ (A/B - C/(D + E)

5. U/V/W/X

___ (U/V)/(W/X)

___ ((U/V)/W)/X

___ (U/V)/W/X

Indicate whether each command is correct or incorrect.

	Correct	Incorrect
6a. FILE PART 6, A AS ITEM 3	___	___
6b. LET H(X) = X * 10 IF Y < 100	___	___
7a. TYPE F(2) * 10↑4 IF 6 < 3 IS FALSE	___	___
7b. DISCARD PART 3	___	___
8a. TYPE FORM 8, X - 98.6, STEP 14.4	___	___
8b. RECALL PART 5	___	___
9a. SET M = M + 1 IF N(I) < TRUE	___	___
9b. SET L(N+1) = N + 1	___	___

Write each of the following expressions in AID notation.

10. $\sqrt{a^2 - b^2}$

11. $\frac{2x + 3y}{xy}$

12. $|m + n + p|$

13. $3x^2 - 2x + 5$

14. $(8.9054) \times 10^{-8}$

15. $(x_1 + x_2) \div (x_3 + x_4)$

16. $x \leq y + 10$

17. $a + b \neq c$

18. $x = \pm 1$

Write the formula for each of the following, using AID notation.

19. The average of the numbers w, x, y, and z.

20. The total price of an item including sales tax if the base price is P and the sales tax is 5%.

_____

For each of the following commands, indicate whether a step number is required.

		Must have step number	Must not have step number	May or may not have step number
21.	DEMAND X	___	___	___
22.	TO STEP 16.2	___	___	___
23.	STOP	___	___	___
24.	DO PART 1	___	___	___

Give the truth value of each of the following expressions.

		T	F
25.	NOT 4 < 3 OR 3 > 4	___	___
26.	X = 12 Y = 15 X < Y OR X+X > Y	___	___

For each of the following programs, list the step numbers in the order in which they would be executed.

27.
```
12.8 DEMAND Q
12.9 SET R = Q + 1
12.10 DEMAND Z
12.95 TYPE R - Z
DO PART 12
```

_____

28.
```
42.1 SET Z = 5
42.2 TO STEP 42.4 IF Z > 0
42.3 SET Z = -Z
42.4 TYPE Z
DO PART 42
```

_____

29.
```
22.1 SET L = 3
22.9 SET L = L + 1
22.75 SET L = L + 1
22.81 DO PART 33 IF L < 5
22.99 TYPE L
33.25 SET L = L + 1
33.35 TYPE L
22.95 SET L = L - 1
DO PART 22
```

For each of the following sets of commands, what numeric result would be typed?

30.
```
LET F(X) = X + 10
TYPE F(2/10)
F(2/10) = _____
```

31.
```
SET A = 16
LET S = A > 10
SET B = TV(S)*A + TV(NOT S)*A*2
TYPE B
B = _____
```

32.
```
SET X = 43.1
SET Y = IP(X)
SET Z = FP(X)
TYPE Y/Z
Y/Z = _____
```

33.
```
TYPE PROD(I = 2, 6, 11: I/2)
PROD(I = 2, 6, 11: I/2) = _____
```

34.
```
SET X = 4596.032
SET Y = DP(X)*10
TYPE Y
Y = _____
```

35.
```
LET F(X) = (X < 10: X+10; X/2)
TYPE F(12)
F(12) = _____
```

36.
```
7.1 SET X = 0
7.2 DO PART 8 FOR N = 1(1)5
7.3 TYPE X
8.1 SET X = X + N
DO PART 7
X = _____
```

37.
```
3.1 SET N = 843.6
3.2 SET P = N/10
3.3 TYPE P IN FORM 3
FORM 3:
P EQUALS ←←.←
DO PART 3
P EQUALS _____
```

38.
```
5.1 SET N = 1
5.2 SET K = 0
5.3 SET F = 5
5.4 SET K = K + N
5.5 SET N = N + 1
5.6 TO STEP 5.4 IF K < F
5.7 TYPE K
DO PART 5
```
K = _____

39.
```
17.1 DO PART 18 FOR I = 1(1)25
17.2 TYPE L(7)
18.1 SET L(I) = I + 2
DO PART 17
```
L(7) = _____

40.
```
22.1 SET T = 0
22.2 DO PART 23 FOR I = 1(1)5
22.3 TYPE T
23.1 DO PART 24 FOR J = 1(1)3
24.1 SET T = T + 1
DO PART 22
```
T = _____

41.
```
34.1 SET X = FIRST(I = 1(1)10: I/2 - 1 > 2.7)
34.2 SET Y = X/2 - 1
34.3 TYPE Y
DO PART 34
```
Y = _____

Rewrite each set of commands, using the fewest possible commands, preserving all indicated actions.

42.
```
DELETE X
DELETE Y
DELETE Z
SET Z = 2.5
```
_____

_____

_____

_____

43.
```
SET W = X + 1
SET W = W/2
SET W = 5 - W
TYPE W
```

44.
```
SET X = 5
DO PART 2
DELETE X
SET X = 6
DO PART 2
DELETE X
SET X = 7
DO PART 2
```

45. Write the AID commands that would cause Part 8 to be put into permanent storage.

46. Write the AID command that would print the value of the natural logarithm (to the base e) of 4.75.

47. Complete step 3.1 in program B below so that programs A and B are equivalent.

Program A

```
1.1 SET A = 1
1.2 TYPE A/3
1.3 SET A = A + 1
1.4 TO STEP 1.2 IF A < 10
DO PART 1
```

Program B

```
3.1 DO PART 4 FOR A = _____
4.1 TYPE A/3
DO PART 3
```

48. Suppose two 9 by 17 arrays A and B are given. The following program produces a new array C such that each element in C is the sum of the elements in the corresponding positions in A and B. Complete step 29.2.

```
27.1 DO PART 28 FOR I = 1(1)9
28.1 DO PART 29 FOR J = 1(1)17
29.2 SET _____________________________________________
DO PART 27
```

49. Write the command that will cause Part 12 to be executed 5 times.

_____

50. The factorial function n! is defined to be $n \cdot (n-1) \cdot (n-2) \cdots 3 \cdot 2 \cdot 1$. For example, $5! = 5 \times 4 \times 3 \times 2 \times 1 = 120$. Write a definition in AID notation of a function f such that $f(n) = n!$.

_____

Introduction to AID Programming 1972-73

Final Examination

Part B

(50 points)

****

DO NOT TURN THE PAGE.

****

Name _____

Student number _____

Instructor's name _____

Name of school or college _____

Date _____

Instructions: Part B is an open-book test; you may use any books, notes, or other materials that you wish. There are 5 programming problems in this part of the final examination. Each problem counts 10 points, and you will be given partial credit for partially correct solutions.

Before you open the test you should be seated at a terminal and signed on. As soon as you sign on, the AID interpreter will start automatically so that you can do the programming problems. If the AID interpreter does not start, raise your hand to get help before the instructor gives the signal to start the test.

For each problem you will be asked to list (print) the completed program and execute it for given values to demonstrate that your program works correctly. This listing and demonstration must be attached to this test and turned in to your instructor for grading. You will have 50 minutes to complete the test.

****

DO NOT TURN THE PAGE UNTIL INSTRUCTED TO DO SO.

****

1. Write a program or a function that will convert degrees Fahrenheit to degrees Kelvin. (From degrees Fahrenheit, subtract 32, multiply by 5/9, and add 273.)

   To turn in for grading: When the program is finished, list it by giving this command:

   TYPE ALL

   Execute the program for 38°F, 0°F, and -41°F. Turn in this part of the teletype paper to your instructor for grading, and then delete the program. (DELETE ALL)

2. Write a program that will compute the wages due, to the nearest penny, for H hours of work if the rate of pay is

   $4.37 per hour for 40 hours or less,
   Time-and-a-half for each hour over 40 hours up to and including the 48th hour,
   Double-time for each hour over the 48th hour.

   To turn in for grading: When the program is finished, list it by giving this command:

   TYPE ALL

   Execute the program for H = 37.25, 42.5, and 52.33 hours. Turn in this part of the teletype paper to your instructor for grading, and then delete the program. (DELETE ALL)

3. Write a program that will calculate postage for a piece of air mail weighing up to and including 16 ounces if the rates are

   11¢ per ounce or fraction of an ounce for 0 to 8 ounces,
   $1.00 total for over 8 ounces up to and including 16 ounces.

   To turn in for grading: When the program is finished, list it by giving this command:

   TYPE ALL

   Execute the program for these weights: 5.2 ounces, 8.7 ounces, 3 ounces. Turn in this part of the teletype paper to your instructor for grading, and then delete the program. (DELETE ALL)

4. Write a program that will calculate the mean and standard deviation of a list $x_1, x_2, x_3, \ldots, x_{10}$ of ten numbers. If M is the mean of the numbers $x_1, x_2, x_3, \ldots, x_{10}$, the formula for the standard deviation is

$$\sqrt{\frac{(x_1 - M)^2 + (x_2 - M)^2 + (x_3 - M)^2 + \cdots + (x_{10} - M)^2}{10}}$$

(continued)

To turn in for grading: When the program is finished, list it by giving this command:

TYPE ALL

Execute the program for this list of numbers:

68
69
72
35
81
53
27
68
73
98

Turn in this part of the teletype paper to your instructor for grading, and then delete the program. (DELETE ALL)

5. Write a program that will approximate the sum of this series:

$$1, \frac{1}{\sqrt{2^2}}, \frac{1}{\sqrt{3^3}}, \frac{1}{\sqrt{4^4}}, \frac{1}{\sqrt{n^n}}, \cdots$$

To approximate the sum, compute successive partial sums until the last partial sum computed is equal to the preceding one, that is, until the n^{th} partial sum is equal to the $(n-1)^{st}$ partial sum. Report the $(n-1)^{st}$ partial sum, and the number of members of the series that were summed to arrive at that approximation.

To turn in for grading: When the program is finished, list it by giving this command:

TYPE ALL

Execute the program to demonstrate that it works correctly. Turn in this part of the teletype paper to your instructor for grading, and then delete the program. (DELETE ALL)

Appendix B

STUDENT EVALUATION FORM
COMPUTER-ASSISTED INSTRUCTION (CAI)

Please read each statement and circle the number on the scale that best describes your feelings.

SCALE

1 Strongly agree
2 Moderately agree
3 Slightly agree
4 Uncertain
5 Slightly disagree
6 Moderately disagree
7 Strongly disagree

1.	I worked as hard answering questions in the computer lessons as I do in the classroom.	1 2 3 4 5 6 7
2.	I learned from the computer lessons as well as I would have learned the same lesson in the classroom.	1 2 3 4 5 6 7
3.	I like working at my own pace at the terminal.	1 2 3 4 5 6 7
4.	I would prefer competing with my fellow students in the classroom rather than working at computer lessons.	1 2 3 4 5 6 7
5.	Working with computer lessons is like having my own tutor.	1 2 3 4 5 6 7
6.	Four hours a week is sufficient time to keep up with the course.	1 2 3 4 5 6 7
7.	I found the computer lessons too easy.	1 2 3 4 5 6 7
8.	I think working with computer lessons is an exciting way to learn.	1 2 3 4 5 6 7
9.	I found working at the terminal more frustrating than worthwhile.	1 2 3 4 5 6 7
10.	I would like to participate in another CAI course.	1 2 3 4 5 6 7

Appendix B (cont.)

11. I found the computer lessons too hard. 1 2 3 4 5 6 7

12. The CAI system provides the student with more feedback than classroom instruction. 1 2 3 4 5 6 7

13. Use the back of this sheet to make any comments you wish concerning the CAI program.

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Footnote

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